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Effect of Carotid Endarterectomy on the Ocular Circulation and on Ocular Symptoms Unrelated to Emboli

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Objective: *To evaluate haemodynamic changes in the ophthalmic artery and the retina following carotid endarterectomy and their effect on the pathophysiology of the eye.*
Design: *Prospective study.*
Method: *Twenty-two consecutive patients with severe carotid stenosis underwent 23 carotid endarterectomies and one subclavian-carotid bypass. The following measurements were made preoperatively and 3 months after operation; Ophthalmic artery (OA) and retinal arteriole (RA) peak systolic velocity (PSV) and peak diastolic velocity (PDV), macular photostress recovery time, visual acuity, intraocular pressures, colour vision and visual fields testing.*
Result: *The RA PSV increased by 50% (p = 0.005) and PDV increased by 22% (p = 0.03). The OA PSV increased by 51% (p = 0.001). Macular photostress testing decreased from 58 s to 42 s (p = 0.001). Visual acuity improved in four and was unchanged in 13 eyes ipsilateral to the endarterectomy which had abnormal preoperative measurements. One patient experienced a dramatic increase in the ipsilateral intraocular pressure associated with visual deterioration. In two patients there was resolution of periorbital pain.*
Conclusion: *Our results demonstrate an increase in the PSV of the RA and OA following carotid surgery. There are pathophysiological changes in the eye, which accompany tight stenotic extracranial carotid artery disease and these may be influenced by carotid endarterectomy.*

Introduction

Amaurosis fugax is the best known ocular symptom of carotid disease. However severe occlusive disease of the extracranial carotid artery may also result in a variety of chronic ischaemic ocular problems, that may lead to permanent blindness secondary to neovascular glaucoma. Eyes that have developed neovascular glaucoma have a poor prognosis, therefore early detection followed by extracranial cerebrovascular evaluation and treatment has the best prognosis for these patients.[1]. Colour Doppler imaging is a simple, reproducible, noninvasive technique, that for the first time makes it possible to assess blood flow velocity in small orbital vessels.[2] The objective of our study was to evaluate the haemodynamic changes in the ocular circulation following carotid endarterectomy and to determine their effect on the pathophysiology of the eye.

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Patients and Methods

Twenty two consecutive patients aged 53–85 years (mean 68) with severe carotid disease were included in this study. The clinical presentation is shown in Table 1. All patients underwent preoperative intra-arterial two plane angiography. Measurements were performed at the point of greatest stenosis and at the normal part of the artery beyond the carotid bulb. The percentage of stenosis was determined by calculating the ratio of these two measurements. The median carotid stenosis in this series was 75% (range 50–100). Bilateral carotid endarterectomies were performed on two patients and the total number of endarterectomies was 23. In addition, one patient with symptomatic

Table 1. Clinical presentation (*n*=22)

	No. of patients
Amaurosis fugax	9
Transient ischaemic attacks	2
Stroke	1
Amaurosis fugax and transient ischaemic attacks	3
Asymptomatic	7

common carotid artery occlusion and patent ipsilateral internal carotid artery was treated with subclavian-internal carotid bypass. Twenty four orbits ipsilateral to the operated carotid were studied 1 day prior to surgery with colour Duplex imaging and 3 months postoperatively. All examinations were performed with a 7.5 MHz linear array transducer (Diasonics, U.S.A.) at a depth of 3.5–5 cm and with reduction of the ultrasound power to 20%. The patients were examined supine with both eyes closed. Coupling gel was placed directly on the closed eyelid. Transverse scans through the orbit were performed with the examiners hand perpendicular to the eyelid. Flow towards the transducer was selected as red and flow away from the transducer as blue (resulting in normal antegrade arterial flow appearing red and normal venous flow appearing blue). The hypoechoic image of the optic nerve was first visualised and the ophthalmic artery was typically identified as a relatively large caliber vessel adjacent to the nerve approximately in 1 cm depth in the retrobulbar space (Fig. 1). The angle of insonation of the probe and the ophthalmic artery was 30°. Retinal flow was measured from retinal arterioles at the 7 or 5 o'clock position (Fig. 2) with a small sample volume placed on the surface of the retina proximal to the vitrous-retina interface. The angle of insonation was 60°. Colour encoded blood flow in the ophthalmic artery and retinal arterioles were initially identified with B-Mode real time ultrasound and subsequently Doppler frequency shifts were measured in these arteries to determine peak systolic flow velocity (PSFV) and peak diastolic flow velocity (PDFV).

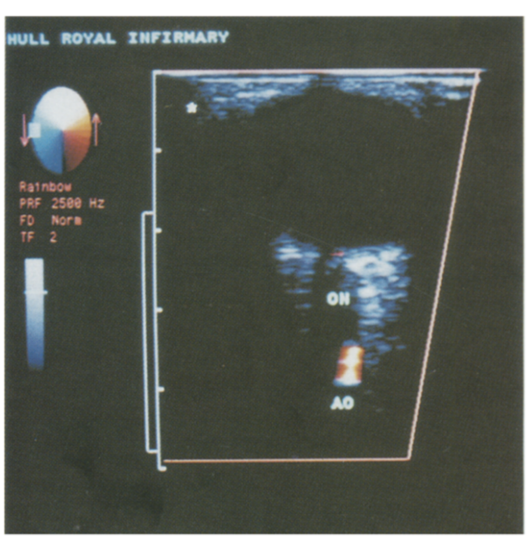

Fig. 1. Transverse scan through the orbit shows the ophthalmic artery (AO) and the ophthalmic nerve (ON).

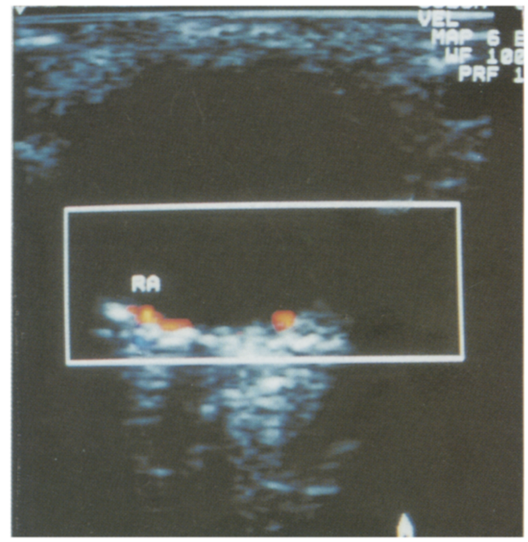

Fig. 2. Transverse scan through the orbit shows a retinal arteriole (RA).

All patients underwent slit-lamp, fundoscopic examination, visual acuity, mascular photostress recovery time, intraocular pressures, colour vision and visual fields testing preoperatively and 3 months after the operation. The macular photostress testing was performed by first evaluating visual acuity at 3 m, using a Snellen chart. Then a 10 s direct photostimulation was carried out with the light source 2 to 3 cm from the eye. As soon as the light source was removed, visual acuity was retested and the time interval between light withdrawal and baseline visual acuity return was recorded. The macular photostress test was performed with the contralateral eye shielded during the examination. The mean photostress recovery time in normal eyes is 27 s, with a standard deviation of 11 seconds.[3] Intraocular pressure was measured using the Goldman applanation tonometer. The ophthalmologist who performed the eye tests was blinded of the ultrasound measurements.

Statistical analysis

For differences between preoperative and postoperative measurements a Student's paired t-test was used. For paired data with no normal distribution the Wilcoxon signed rank test was used. $p < 0.05$ was considered significant.

Results

The 22 patients had a mean age of 68 years (range

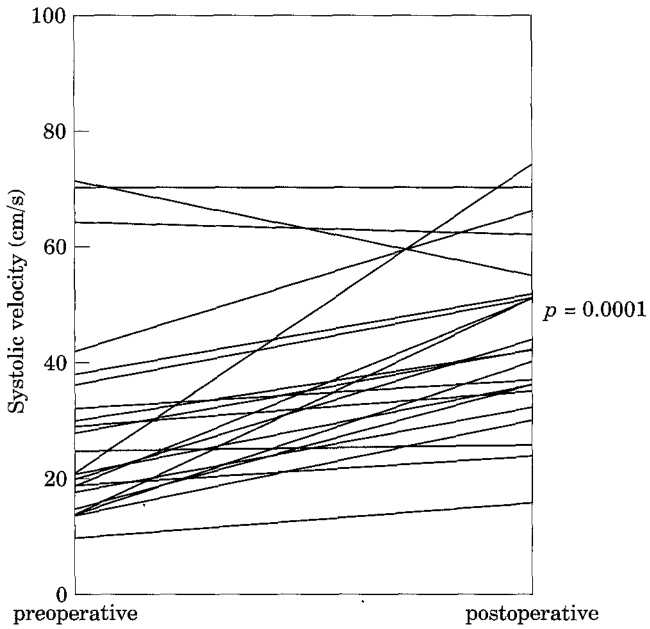

Fig. 3. Systolic velocity in the ophthalmic artery before and after the carotid endarterectomy.

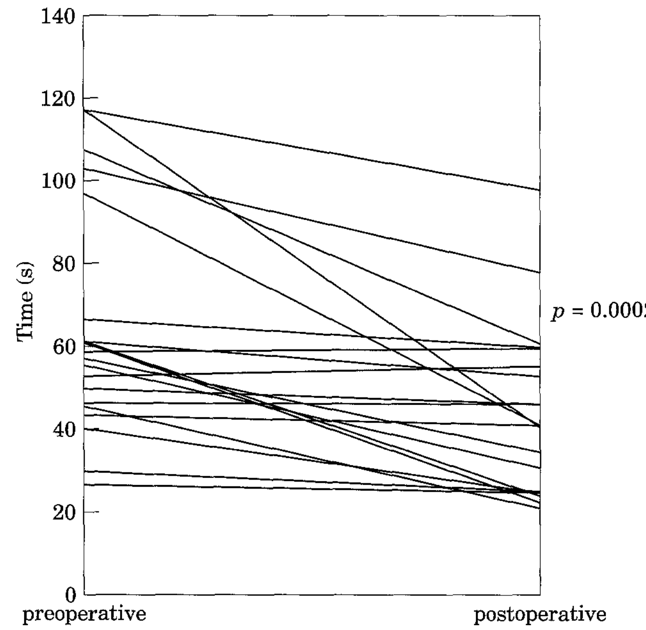

Fig. 4. Macular photostress test before and after the carotid endarterectomy.

53–85). The mean PSF significantly increased in the OA from 29 cm/s to 44 cm/s (p = 0.0001, Fig. 3). The increase in the mean PDFV was not statistically significant (Table 2). The mean PSFV significantly increased in the RA from 36 cm/s to 54 cm/s (p = 0.0005). In the same artery there was a significant increase in the mean PDFV from 10.9 cm/s to 13.4 cm/s (p = 0.03). Macular photostress testing revealed attenuation in the visual evoked response (Fig. 4). The median preoperative time of 58 s (range 26–121) decreased to 42 s (range 20–100), (p = 0.0002 Wilcoxon signed rank test). The improvement was most pronounced on the four patients who had the most abnormal preoperative macular photostress recovery time (Fig. 3). The intraocular pressures and colour vision did not change significantly. One patient with bilateral 90% internal carotid artery stenosis and external carotid arteries occlusion experienced a dramatic increase in the ipsilateral intraocular pressure associated with visual deterioration. The preoperatively visual acuity of the affected eye was 6/24, at 3 months following surgery it was reduced to hand movement. This patient with neovascularisation of the retina and the iris on fundoscopy was the only patient with ocular ischaemic syndrome, an incidence of 4% (Fig. 4). The visual acuity improved in four and was unchanged in 13 eyes that had preoperatively abnormal measurements ipsilateral to the endarterectomy. There was improvement in the visual field in two of the three patients who were found to have visual field impairment preoperatively. In two patients there was resolution of periorbital pain.

Table 2. Values of blood flow velocities in the ocular circulation before and after carotid endarterectomy

	Before endarterectomy	After endarterectomy	p*
Systolic velocity OA (cm/s)	29 (21–36)	44 (38–50)	0.0001
Diastolic velocity OA (cm/s)	9.2 (6.2–12.3)	10.9 (9–12)	0.24
Systolic velocity RA (cm/s)	36 (29–44)	54 (46–62)	0.0005
Diastolic velocity RA (cm/s)	10.9 (9–12)	13.2 (11–15)	0.03

Values in parentheses ae 95% confidence limits; OA, Ophthalmic artery; RA, Retinal arteriole; *Student's t-test.

Discussion

Colour Duplex imaging provides quantitative data about the retro-orbital blood flow characteristics in a rapid, noninvasive way. However current colour Duplex imaging technology cannot determine volumetric flow within the small caliber vessels of the orbital circulation because, as a result of limitations in the spatial resolution, the diameters of these arteries cannot be accurately assessed. Hu *et al.* in a recent study have shown that there is a linear association between PSFV in the central retinal artery and ophthalmic artery systolic pressure measured by ocular pneumoplethysmography and ophthalmodynamography.[4] Our results confirm the assumption that following carotid endarterectomy there is an increased PSFV in the ocular circulation. The mean PSFV in the OA is similar to that reported elsewhere for patients with severe carotid stenosis.[5] However the mean PDFV was higher than previously reported. There was also a significant postoperative increase in the mean PSV and PDV of the RA. There was no trend for a decreased PSV and PDV for an increasing degree of carotid artery stenosis, indicating that probably the status of the circle of Willis is an important determinant of the velocities in the orbital circulation. This hypothesis needs to be tested with further work assessing the cerebral haemodynamics.

A significant improvement was noted on the macular photostress recovery time following endarterectomy. In two patients there was no change. This test examines the functional ability of the macula by recording the time of recovery of central vision following illumination of the macula with the light of the ophthalmoscope or a penlight.[6,7] Retinal ischaemia leads to an inadequate regeneration of retinal photosensitive pigments and this may result in a prolongation of the visual acuity recovering time after bright light stimulation. In advanced cases there may be transient visual loss after exposure to bright light, a condition also known as light induced amaurosis.[8] Improvement of photostress recovery time after endarterectomy has been also reported by others.[1]

Ocular ischaemic syndrome may occur in patients who have either ipsilateral common carotid artery obstruction or critical bilateral internal carotid arteries stenosis.[9] This syndrome begins with a retinopathy and consists of a progressive series of ischaemic changes in the posterior and anterior segment of the eye giving rise to neovascular glaucoma. Pathophysiologically, critical carotid artery stenosis or occlusion may produce, in cases associated with poor collateral circulation via the circle of Willis, chronic ophthalmic artery insufficiency. This condition induces chronic retinal hypoxia and may precipitate neovascularisation of the retina, rapid lenticular changes and neovascularisation of the iris. The proliferating fibrovascular tissue obstructs the iridocorneal angle and restricts the absorption of aqueous humour from the canal of Schlemm. Once neovascular glaucoma has been developed it is unlikely that it will improve following carotid endarterectomy because the new vessels do not always regress when the prior hypoxic stimulation has been eliminated.[10] Some success for the treatment of this condition has been reported with either the use of panretinal photocoagulation,[11] or the insertion of the Molteno implant which provides drainage of the anterior chamber by a silicone tube placed through the scleral tunnel,[12] or cyclocryotherapy.[13] Early detection by an ophthalmologist followed by extracranial cerebrovascular evaluation and treatment offers the best management for this blinding disease.[1] There was only one patient with ocular ischaemic syndrome in this series an incidence of 4%, which is similar to previous reports.[14]

Ciliary body ischaemia may cause normal or low intraocular pressures in patients with ocular ischaemic syndrome. These patients may develop increased intraocular pressures following endarterectomy because of increased production of aqueous humour when the ciliary body regains improved blood supply.[10,12] In our case the intraocular pressure increased from 17 to 35 mmHg. It is noteworthy that this case was only identified because of the careful monitoring of this series. Eye signs and symptoms in patients with ischaemic ocular syndrome can be mimicked by diabetes, central retinal vein occlusion and uveitis.[13]

Ischaemic pain in the orbit may be a feature of critical carotid stenosis.[1,9,14,15] It is usually described as a constant heaviness or aching over the orbit, upper part of the face and the temple. This pain is not related to glaucoma, which may also produce periorbital pain and can be distinguished by normal intraocular pressures. Carotid endarterectomy resulted in immediate resolution of the pain on the two patients in our series a finding consistent with a previous report.[15] On both patients there was more than 100% increase in the velocities of the OA and the RA following the endarterectomy.

In conclusion we have shown that transorbital colour flow imaging can evaluate changes in the ocular circulation following carotid endarterectomy. In addition we have demonstrated that there are pathophysiological changes in the eye, which accompany tight stenotic extracranial carotid artery disease and these may be influenced by carotid endarterectomy.

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